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Seed Source Selection of Eastern White Pine

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Introduction

Eastern white pine (*Pinus strobus* L.) is Ontario's provincial tree. Its large and straight stems, often accompanied by unique crown shapes, act with the rocks, water, and sky to create preferred, highly valued recreation and tourism areas in Ontario. Fallen stems of old white pine trees often provide preferred habitats for wildlife. Its economic value makes white pine an ideal species for forest industry. Its growth rate and adaptability also make it an important species for enhancing forest productivity and increasing carbon sequestration.

Eastern white pine's natural range stretches from southeastern United States to central Ontario, Canada. Like many forest species, natural selection and adaptive evolution have left their mark on eastern white pine, resulting in population variation and differentiation. For example, range-wide seed source tests have revealed substantial genetic variation in growth potential among geographic populations (Fowler and Heimburger 1969, Garrett et al. 1973, Genys 1987, Abubaker and Zsuffa 1991, Li et al. 1997). Genetic variation in growth among seed sources provides an opportunity to achieve large, fast, and inexpensive genetic gains in reforestation programs to enhance forest productivity and carbon sequestration, provided that appropriate seed sources are used (Zobel and Talbert 1984). On the other hand, poorly guided movement of seeds among locations may result in maladaptation and loss of productivity (Rehfeldt 1986, Matyas and Yeatman 1992). Local seed source testing is therefore required to balance growth gains and risk of climate-related damage.

Project Objectives and Design

The objectives of this project were:

- To complete data collection and analysis for white pine seed source trials to provide information on growth potential and adaptability across Ontario
- To collect data on frost damage tolerance for each seed source through a series of laboratory freezing tests
- To assess and revise existing seed source selection guidelines to maximize white pine growth and minimize potential risk of cold damage.

This project was an extension of a white pine genecology research trial initiated by the Ontario Forest Research Institute in the early 1990s. Seeds were collected from 112 natural populations of white pine across Ontario. Seed sources ranged from 42.9° to 48.3° N latitude, from 74.4° to 84.7° W longitude, and from 53 to 520 m in elevation (Figure 1). Growth potential and adaptation were tested for 2 years in the greenhouse, and for 5 more years in 2 field trials. Additional data were collected under artificially simulated extreme weather conditions to test the frost damage tolerance of the white pine seed sources (Figure 2).



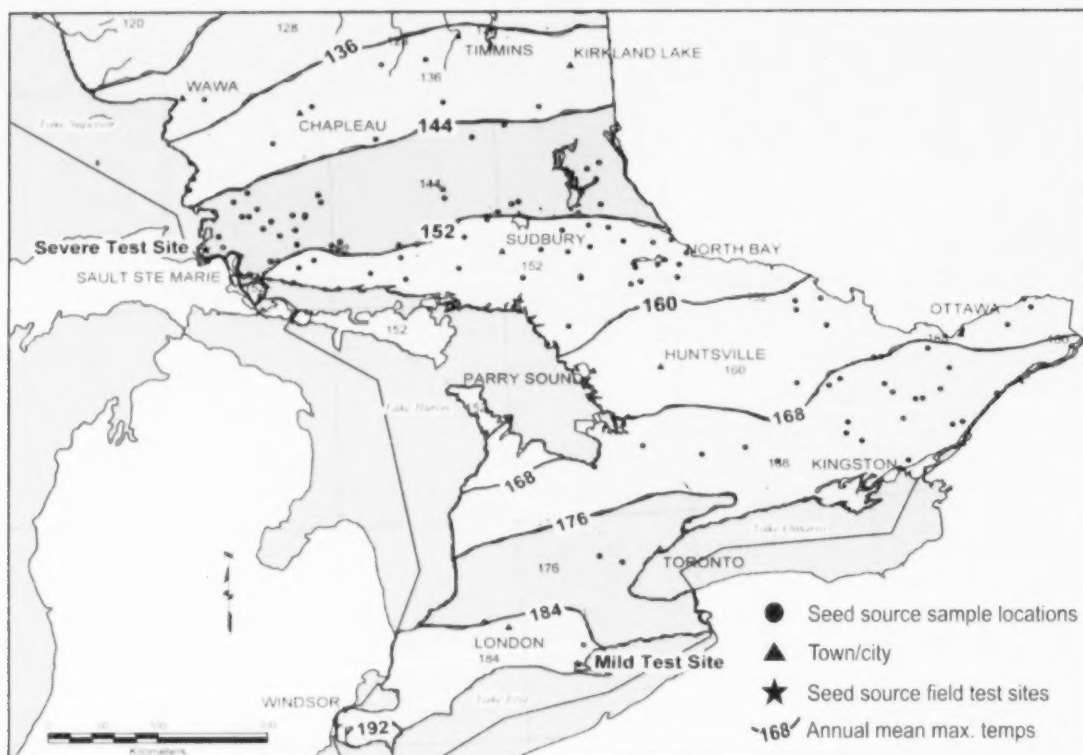


Figure 1. Seed source sample locations, field test sites and the annual mean maximum temperatures ($^{\circ}\text{C}$) in the eastern part of Ontario.

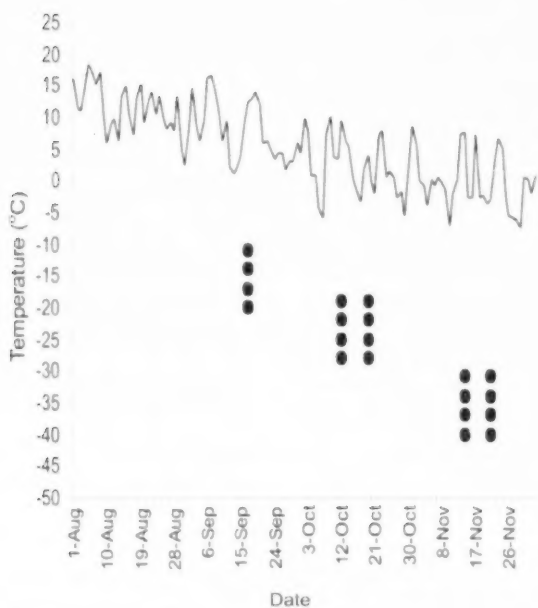


Figure 2. An illustration of artificial freezing test conditions. The line indicates daily minimum temperature at 1.5 m aboveground at the field test in Sault Ste. Marie in 2001. Dots indicate needle and shoot sample collection dates and freezing temperatures in the freezing tests.

Key Findings

1. Genetic variation in growth potential among seed sources

Greenhouse and field trials have revealed that considerable genetic variation in growth potential exists among eastern white pine seed sources in Ontario. Genetic variation among seed sources accounted for 17 - 19% of the phenotypic variance in seedling height and 11 - 22.5% in 5-year-old tree height, which suggests that the use of fast-growing seed sources can significantly increase forest productivity and carbon sequestration in Ontario (Joyce et al. 2002). A strong geographic pattern in growth potential was detected among seed sources. In general, seed sources from more southerly and warmer areas grew faster than those from more northerly and colder areas (Figure 3). In a multiple regression analysis, 2 to 4 climatic and geographic variables explained 50 - 65% of the fifth-year mean height growth differences among seed sources in the field tests. Furthermore, latitude alone accounted for 36.7 - 63.6% of the variation in fifth-year mean

height. In Sault Ste Marie, seed source growth potential, in terms of height growth at age 5, can be predicted by the equation:

$$\text{Mean_height (cm)} = 587.78 + 0.1632 \cdot \text{ADD} - 10.211 \cdot \text{latitude} \quad (R^2 = 0.656)$$

Where ADD is the aggregated degree days above 5°C in the first 6 weeks of the growing season. This equation predicts that moving a seed source northward by 1.0° in latitude would increase fifth-year mean height growth by about 6.5%. On the other hand, moving a seed source southward by 1.0° in latitude would decrease height growth potential by 6.5%.

2. Genetic variation in cold hardiness among seed sources

The artificial freezing tests revealed that cold hardiness increases from September to November as tree acclimation progresses (Figure 4). As a species, white pine can withstand fairly extreme climate events at different cold acclimation stages in the fall and winter. For example, needles of greenhouse grown seedlings could tolerate -7°C temperatures without damage when taken directly from a greenhouse growing environment of 28°C (day)/18°C (night). Needle and cambium tissues of field trees could tolerate -14°C, -19°C and -31°C in mid September, October, and November, respectively, in Sault Ste. Marie, which exceeded local extreme low temperatures documented since 1955 (Lu et al. 2003a).

Like growth potential, a clinal pattern of variation in cold damage among seed sources was detected under freezing temperatures that were low enough to cause needle and cambium damage (Figure 5). The cold hardiness trend parallels that of growth potential, but in the opposite directions. Seed sources from the warmer and more southerly areas generally have high growth potential, but are less cold hardy than those from colder and more northerly areas, although the trend is not as strong as for growth potential (Figure 3).

3. Seed source selection recommendations

To maximize white pine growth and at the same time maintain a high degree of adaptation in terms of cold hardiness, a compromise between growth potential and the capacity to tolerate winter climate extremes is necessary. Based on statistical analyses of the scales and patterns of geographic variation of these and other traits (Lu et al., 2003b), recommendations for seed source selection are as follows:

- Using seed sources from 1.0° – 1.5° (latitude) north of a given reforestation area is not recommended due to potential decreases in future growth
- Using seed sources from 1.5° – 2.0° (latitude) south of a given reforestation area may promote white pine growth, without incurring more frost damage risk than that if local seed sources were used
- A 6.5 - 13.0% gain in height growth can be expected by selecting a seed source from within 1.0° – 2.0° (latitude) of the reforestation area relative to using seed sources from outside that area

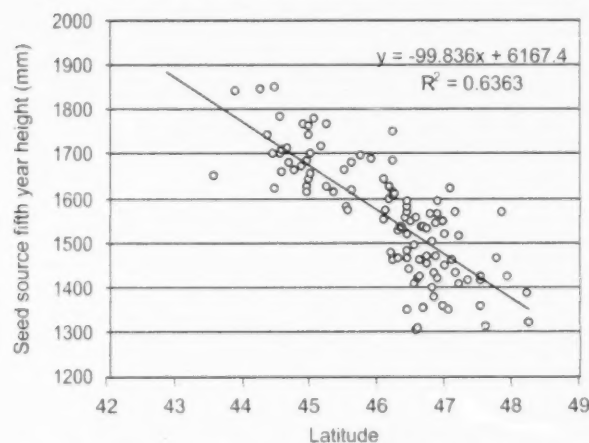


Figure 3. Relationship between seed source growth potential and latitude of seed source origin.

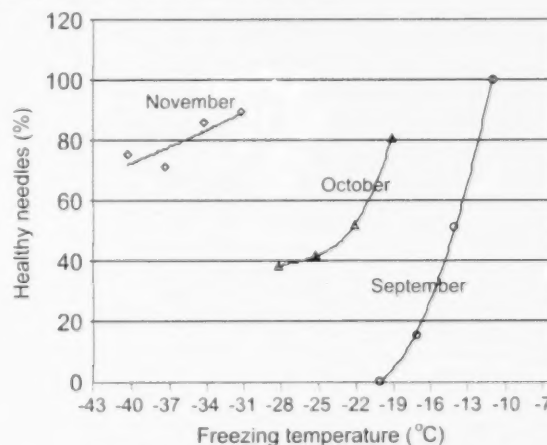


Figure 4. An illustration of the change in white pine cold hardiness. Decreasing freezing temperatures increased cold damage more in September than in October and November.

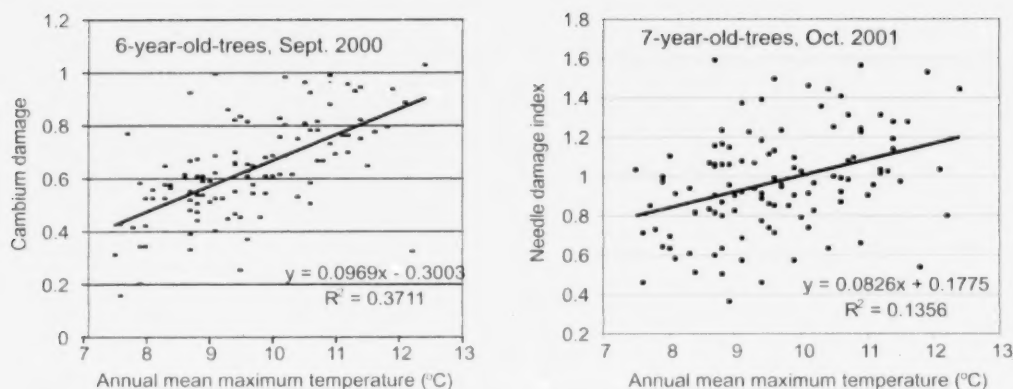


Figure 5. Relationship between cold damage and the annual mean maximum temperature at seed source origins in two consecutive years.

Future Work

Climate surfaces of Ontario that are based on minimum fall and winter temperatures would assist decisionmakers in selecting white pine seed sources across regions. Data on the minimum threshold temperatures that result in cold damage for each seed source could then be compared with the minimum temperatures in the region to evaluate the risks associated with using a more southerly seed source to increase growth.

Acknowledgements

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